Renewable and Sustainable Energy Reviews 15 (2011) 4466–4469

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Does natural gas consumption follow a nonlinear path over time? Evidence from 50 US States

Alper Aslan*

Nevsehir University, Faculty of Economics and Administrative Sciences, 50300 Nevsehir, Turkey

ARTICLE INFO

Article history:
Received 27 March 2011
Accepted 5 July 2011
Available online 15 September 2011

Keywords:
Natural gas consumption
ESTAR
Structural break

ABSTRACT

This study is the first attempt to investigate the stationarity of natural gas consumption for 50 US states by employing nonlinear unit root test over the period 1960–2008. We concluded that natural gas consumption in approximately over 60% of states follow a nonlinear behavior. While for 27 US states, natural gas consumption is a non-stationary process, then any shock to natural gas consumption is likely to be permanent and such policies will have a permanent impact, for the rest of 23 states natural gas consumption is a stationary process that any shock to natural gas consumption is to be transitory.

Contents

1. Introduction

It is crucial to understand the stationary properties of energy consumption because if energy consumption follows a stationary process, energy demand management policies designed to shrink energy consumption will have temporary effects as energy consumption will return to its trend path. However, if energy consumption is a non-stationary, then any shock to energy consumption is possible to be permanent and such policies will have a permanent impact. In addition, if energy consumption does not contain a unit root, then the past behavior of energy consumption will be of use in formulating forecasts.

These cases make the issue of the stationary properties of energy consumption vitally important to understand. Therefore, there have been a number of studies examining the unit root properties of energy consumption in the literature such as Chen and Lee [1], Narayan and Smyth [2], Hsu et al. [3] and Mishra et al. [4], Lean and Smyth [5], and Narayan et al. [6], Apergis et al. [12,13] and Apergis and Payne [7]. However, these previous studies that focus exclusively on whether or not energy consumption is stationary have yielded mixed results. In this study, we examine the stationarity of natural gas consumption for each of the 50 states. This short communication will employ [8] unit root test, which is an improved version of the Kapetanios et al. [14] test to decide which series are stationary. Prior to the Kruse [8] test, the adequacy of the nonlinear behavior under the alternative hypothesis is confirmed by testing the hypothesis of linearity vs. nonlinearity by means of the Harvey et al. [9] test. This study is the first attempt to investigate the stationarity of natural gas consumption for 50 US states by non linear test. While Apergis et al. [13] examined the stationarity of natural gas consumption for 50 US states by linear unit root test; we concluded that the hypothesis of linearity is rejected in 31 cases in 50 states. Since if energy consumption follow a nonlinear path over time, traditional (linear unit root tests) may suffer from power problems, i.e. they tend to over accept the null hypothesis, we employed non linear unit root test for the cases which show nonlinear behavior.

The rest of the paper is organized as follows. In Section 2, we provide the data, methodology and results. In Section 3, we provide some concluding comments.

* Corresponding author. Tel.: +90 384 228 11 10/1519; fax: +90 384 2152010.
E-mail address: alperleo@gmail.com

1364-0321/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2011.07.105

Table 1
Linearity test results.

States	Statistics	Prob. value	Result	States	Statistics	Prob. value	Result
Alabama	3.168	0.530	Linear	Missouri	28.575	0.000	Non linear
Alaska	3.863	0.425	Linear	Montana	7.877	0.096	Non linear
Arizona	78.339	0.000	Non linear	Nebraska	18.082	0.001	Non linear
Arkansas	7.675	0.104	Linear	Nevada	25.372	0.000	Non linear
California	34.390	0.000	Non linear	New Hampshire	53.922	0.000	Non linear
Colorado	7.474	0.113	Linear	New Jersey	99.348	0.000	Non linear
Connecticut	7.225	0.124	Linear	New Mexico	11.158	0.025	Non linear
Delaware	1.734	0.785	Linear	New York	11.721	0.020	Non linear
District of Columbia	1.518	0.823	Linear	North Carolina	11.160	0.025	Non linear
Florida	36.224	0.000	Non linear	Ohio	10.257	0.036	Non linear
Georgia	12.845	0.012	Non linear	Oklahoma	15.339	0.004	Non linear
Hawaii	0.907	0.924	Linear	Oregon	17.159	0.002	Non linear
Idaho	16.334	0.003	Non linear	Pennsylvania	4.538	0.338	Linear
Illinois	5.344	0.254	Linear	Rhode Island	6.630	0.157	Linear
Indiana	70.732	0.000	Non linear	South Carolina	14.113	0.007	Non linear
Iowa	13.450	0.009	Non linear	South Dakota	3.935	0.415	Linear
Kansas	15.809	0.003	Non linear	Tennessee	237.825	0.000	Non linear
Kentucky	2.254	0.689	Linear	Texas	4.997	0.288	Linear
Louisiana	388.08	0.000	Non linear	Utah	7.000	0.136	Linear
Maine	8.010	0.091	Non linear	Vermont	48.644	0.000	Non linear
Maryland	4.928	0.295	Linear	Virginia	9.829	0.043	Non linear
Massachusetts	17.067	0.002	Non linear	Washington	24.863	0.000	Non linear
Michigan	6.056	0.195	Linear	West Virginia	11.649	0.020	Non linear
Minnesota	17.821	0.001	Non linear	Wisconsin	7.310	0.120	Linear
Mississippi	4.623	0.328	Linear	Wyoming	68.391	0.000	Non linear

Note: The 1%, 5%, and 10% critical values for Harvey et al. [9] test: 7.779, 9.488, and 13.277.

Table 2
LM univariate test results.

	LM univariate	k	LM univariate with one break	k	TB	LM univariate with two breaks	k	TB1	TB2	
Alabama	−5.127	5	−6.289	5	2001	−8.357	1	1981	1985	Stationary
Alaska	−1.856	7	−5.382	5	1970	−8.589	1	1971	1981	Stationary with break
Arkansas	−1.045	3	−3.563	3	2000	−5.628	5	1976	2000	Stationary with break
Colorado	−1.353	7	−3.614	5	1975	−7.708	1	1972	1987	Stationary with break
Connecticut	−3.435	5	−9.485	1	1984	−10.185	1	1998	2003	Stationary
Delaware	−1.301	6	−4.882	5	2000	−8.333	1	1977	2000	Stationary with break
District of Columbia	−2.858	3	−8.926	1	1996	−9.108	1	1972	1996	Stationary
Hawaii	−3.128	6	−5.631	1	1979	−7.543	5	1970	1980	Stationary
Illinois	−4.053	5	−4.532	5	2001	−8.654	1	1987	1999	Stationary
Kentucky	−3.228	8	−6.780	1	1970	−7.917	1	1977	1987	Stationary
Maryland	−4.416	5	−5.916	5	1977	−6.587	5	1971	1996	Stationary
Michigan	−2.626	8	−4.283	8	1993	−5.631	8	1988	1996	Stationary with break
Mississippi	−3.288	5	−3.955	7	1989	−10.076	1	1985	1996	Stationary
Pennsylvania	−0.665	6	−9.150	1	1999	−9.370	1	1980	1999	Stationary with break
Rhode Island	−8.249	1	−9.390	1	1981	−9.998	1	1972	1980	Stationary
South Dakota	−2.789	3	−8.039	1	1992	−11.198	1	1977	1993	Stationary with break
Texas	−1.157	4	−5.336	3	1974	−12.908	1	1975	1991	Stationary with break
Utah	−1.958	4	−5.777	6	1971	−9.240	1	1975	1999	Stationary with break
Wisconsin	−2.766	3	−9.579	1	1975	−11.306	1	1977	1989	Stationary with break

Notes: Numbers in the parentheses are the optimal number of lagged first-differenced terms included in the unit root test to correct for serial correlation. The 1, 5, and 10% critical values for the LM unit root test with no break are: −3.63, −3.06, and −2.77. The 1%, 5%, and 10% critical values for the minimum LM test with one break are: −4.239, −3.566, and −3.211. The 1%, 5%, and 10% critical values for the minimum LM test with two breaks are: −4.545, −3.842, and −3.504, respectively.

2. Data, methodology and results

U.S. data for each of the 50 states on natural gas consumption was obtained from the Energy Information Administration. Natural gas consumption is defined in billion of cubic feet for 1960–2008. All data have been converted to natural logarithms. Kapetanios et al. [14] propose a unit root test against the alternative of globally stationary exponential smooth transition autoregression (ESTAR).

$$y_t = \beta y_{t-1} + \phi y_{t-1} F(\Theta; y_{t-1}) + \varepsilon_t \tag{1}$$

Where ε_t is *iid* $(0, \sigma^2)$ and $F(\Theta\,; y_{t-1})$ is the transition function, which is assumed to be exponential,

$$F(\Theta;\ y_{t-1}) = 1 - \exp\{-\Theta(y_{t-1} - c)^2\} \text{ with } \Theta \rangle 0.$$

However, Kapetanios et al. [14] assume that $c = 0$.

$$\Delta y_t = \alpha y_{t-1} + \gamma y_{t-1}(1 - \exp\{-\Theta y_{t-1}^2\}) + \varepsilon_t \tag{2}$$

Kapetanios et al. [14] impose $\alpha = 0$. The null hypothesis H_0: $\Theta = 0$ is tested against the alternative $H_1: \Theta \rangle 0$. The idea of Kapetanios et al. [14] of imposing $c = 0$ may be too restrictive for variables where the threshold value may be different from 0. That is why in this paper, we apply Kruse's [8] test, which is an extension of the Kapetanios et al. [14] unit root test, which relaxes the assumption of a zero location parameter c. Kruse [8] considers the following modified ADF regression

$$\Delta y_t = \alpha y_{t-1} + \gamma y_{t-1}(1 - \exp\ \{-\Theta(y_{t-1} - c)^2\}) + \varepsilon_t \tag{3}$$

Table 3
ESTAR unit root test results.

States	KSS		States	KSS	
Arizona	0.1332	Non stationarity	Nevada	−1.444	Non Stationarity
California	−3.377	Stationary	New Hampshire	−2.261	Non Stationarity
Florida	−0.894	Non stationarity	New Jersey	−2.215	Non Stationarity
Georgia	−1.920	Non stationarity	New Mexico	−1.373	Non Stationarity
Idaho	−1.693	Non stationarity	New York	−1.704	Non Stationarity
Indiana	−2.193	Non stationarity	North Carolina	−1.930	Non Stationarity
Iowa	−1.377	Non stationarity	Ohio	−2.523	Non Stationarity
Kansas	−1.279	Non stationarity	Oklahoma	−5.799	Stationary
Louisiana	−8.245	Stationary	Oregon	−1.988	Non Stationarity
Maine	−0.354	Non stationarity	South Carolina	−2.390	Non Stationarity
Massachusetts	−2.650	Non stationarity	Tennessee	−2.285	Non Stationarity
Minnesota	−2.406	Non stationarity	Vermont	−7.591	Stationary
Missouri	−1.310	Non stationarity	Virginia	−2.262	Non Stationarity
Montana	−1.653	Non stationarity	Washington	−2.507	Non Stationarity
Nebraska	−1.335	Non stationarity	West Virginia	−1.550	Non Stationarity
			Wyoming	−1.319	Non Stationarity

Note: The 1%, 5%, and 10% critical values for Kruse [8] test: −3.48, −2.93, and −2.66, respectively.

Following Kapetanios et al. [14], it is possible to obtain a first order Taylor approximation

$$\Delta y_t = \delta_1 y^3 t - 1 + \delta_2 y^2 t - 1 + \varepsilon_t \quad (4)$$

To test the null hypothesis of linearity against the alternative of a nonlinear model, we apply Harvey et al. [9]. This test runs better in terms of size and power than those proposed by Harvey and Leybourne [10].

For linear relation, LM unit root test which is developed by Lee and Strazicich [11] is employed. The break minimum LM unit root can be described as follows:

$$\Delta r_{it} = \delta' \Delta Z_t + \phi \bar{S}_{t-1} + \mu_t \quad (5)$$

Here, Δ is the first difference operator; $\bar{S}_t = r_t - \hat{\Psi}_x - Z_t\hat{\delta}_t$ $t = 2,\ldots T$; $\hat{\delta}$ are coefficients in the regression of Δr_t on ΔZ_t; $\hat{\Psi}_x$ is given by $r_t - Z_t\delta$. If energy consumption has a unit root for state i then $\phi_t = 0$, which is the null hypothesis tested using the t-test against the alternative hypothesis that $\phi_t < 0$. The panel LM test statistic is obtained by averaging the optimal univariate LM unit root t-test statistic estimated for each state (Table 1). This is denoted as LM_i^τ

$$\mathrm{LM}_{\mathrm{barNT}} = \frac{1}{N}\sum_{i=1}^{N} \mathrm{LM}_i^\tau \quad (6)$$

In Table 2, we display the results of the individual unit root tests and linearity test. In order to decide whether to introduce nonlinearities under the alternative hypothesis, we first apply the linearity test by Harvey et al. [9].

The hypothesis of linearity is, hence, rejected in 31 cases in 50 states. We have applied LM univariate linear unit root tests, along with the Kruse [8] test. When the linearity hypothesis is rejected we find that using the Kruse [8] test (Table 3).

The unit root null is not rejected for Alabama, Illinois, Maryland and Rhode Island at the 1% level. The failure to find stationarity in exchange rate series may be due to the fact that univariate unit root tests have low power when structural breaks are ignored. To cope with this problem, we investigated the integrational properties of natural gas consumption by LM unit root test with structural breaks.

When we consider LM unit root test with structural breaks, the unit root null is rejected for 19 US states which illustrate linear behavior. These means that energy demand management policies designed to shrink natural gas consumption will have transitory effects as natural gas consumption will return to its trend path.

On the other hand, we investigate the other 31 states' natural gas consumption which illustrate nonlinear path in order to decide the stationary properties of natural gas consumption by Kruse's [8] test which is a developed version of ESTAR.

The unit root null is rejected Arizona, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Maine, Massachusetts, Minnesota, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oregon, South Carolina, Tennessee, Virginia, Washington, West Virginia and Wyoming. For these 27 states, natural gas consumption is a non-stationary process (i.e. contains a unit root), then any shock to natural gas consumption is likely to be permanent and such policies will have a permanent impact on these 27 countries. However for the state of California, Louisiana, Oklahoma and Vermont, gas consumption is a stationary process that any shock to natural gas consumption is likely to be transitory and such policies will have a temporary impact.

3. Concluding remarks

There has been a growing interest in applying unit root tests to examine the stationarity properties of energy consumption. Interest in whether energy consumption is stationary is motivated by a number of factors. First, if energy consumption follows a stationary process, energy demand management policies designed to shrink energy consumption will have temporary effects as energy consumption will return to its trend path. However, if energy consumption is a non-stationary, then any shock to energy consumption is possible to be permanent and such policies will have a permanent impact. Second, if energy consumption does not contain a unit root, then the past behavior of energy consumption will be of use in formulating forecasts.

Unlike previous papers that have been applied linear unit root test to examine the stationarity of energy consumption, we apply linearity test to decide whether natural gas consumption follow a nonlinear or linear path for 50 US over the period 1960–2008. Surprisingly, we concluded that natural gas consumption in approximately over 60% of states in US follow a nonlinear behavior, then we found that while for 27 US states, natural gas consumption is a non-stationary process, then any shock to natural gas consumption is likely to be permanent and such policies will have a permanent impact, for the rest of 23 states natural gas consumption is a stationary process that any shock to natural gas consumption is to be transitory.

References

[1] Chen PF, Lee CC. Is energy consumption per capita broken stationary? New evidence from regional-based panels. Energy Policy 2007;35:3526–40.

[2] Narayan R, Smyth R. Are shocks to energy consumption permanent or transitory? Evidence from 182 countries. Energy Policy 2007;35: 333–41.
[3] Hsu C, Lee CC, Lee CC. Revisited: are shocks to energy consumption permanent or temporary? New evidence from a panel SURADF approach. Energy Econ 2008;30:2314–30.
[4] Mishra V, Sharma S, Smyth R. Are fluctuations in energy consumption per capita transitory? Evidence from a panel of Pacific Island Countries. Energy Policy 2009;37:2318–26.
[5] Lean HH, Smyth R. Long memory in US disaggregated petroleum consumption: evidence from univariate and multivariate LM tests for fractional integration. Energy Policy 2009:3205–11.
[6] Narayan PK, Narayan S. Popp S. Energy consumption at the state level: the unit root null hypothesis from Australia. Appl Energy 2010;87: 1953–62.
[7] Apergis N, Payne JE. Structural breaks and petroleum consumption in US states: are shocks transitory or permanent? Energy Policy 2010;38:6375–8.
[8] Kruse R. A new unit root test against ESTAR based on a class of modified statistics. Statistical Papers 2011;52:71–85.
[9] Harvey DI, Leybourne SJ, Xiao B. A powerful test for linearity when the order of integration is unknown. Stud Nonlinear Dyn Econometrics 2008;12(3), article 2.
[10] Harvey DI, Leybourne SJ. Testing for time series linearity. Econometrics J 2007;10:149–65.
[11] Lee J, Strazicich MC. Minimum LM unit root test with two structural breaks. Rev Econ Stat 2003;63:1082–9.
[12] Apergis N, Loomis D, Payne JE. Are fluctuations in coal consumption transitory or permanent? Evidence from a panel of US states. Appl Energy 2010;87:2424–6.
[13] Apergis N, Loomis D, Payne JE. Are shocks to natural gas consumption temporary or permanent? Evidence from a panel of US States. Energy Policy 2010;38:4734–6.
[14] Kapetanios G, Shin Y, Snell A. Testing for a unit root in the nonlinear STAR framework. J Econometrics 2003;112:359–79.